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TAGGING COUNTERS FOR ELECTRONS IN THE 100-GeV RANGE

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Introduction

The synchrotron radiation of electrons in the beam-deflecting magnets of a beam-transport system can provide an excellent tagging counter for electrons in the 100-GeV range. Threshold Cerenkov counters for electrons will require extreme lengths and differential Cerenkov counters are possible, but difficult. This note will discuss Cerenkov counter limitations and some of the design considerations for tagging counters using synchrotron radiation. It will also point out the use of synchrotron radiation in making a separated electron beam.

Threshold Cerenkov Counters

A Cerenkov counter produces light at an angle θ^2 given by

$$\theta^2 \simeq 2(n-1) - \frac{1}{\gamma^2} ,$$

where n is the index of refraction. Consider a counter in a 110 GeV/c momentum-analyzed beam so that $\gamma_\mu = 1000$. Hence, the pressure for μ meson threshold is such that the index of refraction n is $1 + 5 \times 10^{-7}$. For hydrogen at atmospheric pressure $n - 1 = 1.4 \times 10^{-4}$ so that the required pressure is approximately 3 mm of Hg. Using Manning's formula for intensity[1] N (photons) = 10^5 L (meters) θ^2 and requiring 50 photons (~ 10 photo electrons) we need a length of 500 meters. The length is going as γ^2.

Differential Cerenkov Counters

Arthur Roberts[2] has considered the use of differential Cerenkov counters for electrons. Present day DISC's could be used up to 50 GeV. For higher energies DISC might be made longer and operated at lower pressures allowing for μ-e separation. Some developmental work would be needed and the counter would require a parallel beam with angular divergencies less than 1 mrad. Hence, it is difficult but possible to make a differential Cerenkov counter for 100 GeV/c separation, again with a difficulty increasing like γ^2.

Synchrotron Radiation Detectors for Electrons

If an electron of energy E (GeV) traverses a field B (in Tesla, 10^4g = 1 T) and length L (meters) then it will lose energy δE (MeV) by synchrotron radiation according to

$$\delta E = 1.3 \times 10^{-3} E^2 B^2 L.$$

For example, at E = 100 GeV, B = 2 T = 20,000 G, and L = 10 m, an electron will lose 500 MeV of energy as synchrotron radiation. The spectrum of radiation extends up to a critical energy E_c given by

$$E_c\,(\text{MeV}) = 2.8 \times 10^{-3}\, B E^2.$$

In the example just given E_c = 50 MeV. The energy loss divided by E_c goes as 1/2 BL, so that any attempt to measure E by the total synchrotron radiation will require a large BL. The intensity spectrum for the 100 GeV example is sketched in Fig. 1.

A typical detector is shown in Fig. 2(a). A total absorption scintillation counter or a solid-state counter is located so as to view some arc of the particle trajectory. Another method which increases the radiation but keeps the detector small is sketched in Fig. 2(b). Here the idea is to put the particle through an alternating field so that the particle has only a small net deflection and hence, the synchrotron radiation detector can be kept small. Depending upon the local backgrounds, thinner, more frequency sensitive detectors could be used. The frequency should not be lower than about one hundredth of E_c. One could split up the detector and ask for many voting counters as another way of reducing the backgrounds.

Sychrotron Radiation by Pions

The synchrotron radiation by a particle of electronic charge and mass M is reduced by a factor of $(M_e/M)^4$ from an electron of the same momentum. For pions this is a factor of 10^{-10}, and hence, synchrotron radiation detectors are not useful in the 100-GeV energy range except for electrons.

Separated Electron Beams

Any momentum-analyzed beam can have its electrons separated by either going through enough subsequent deflector or bumpy alternating field so that the electrons lose several times the energy corresponding to the Δp of the beam. This will become easier the higher the energy of the beam and for smaller Δp.

REFERENCES

[1] G. Manning, CERN/ECFA, Vol. I, p. 253.

[2] A. Roberts, Lawrence Radiation Laboratory UCRL-16830, Vol. III, p. 192.

GENERAL REFERENCES

1. J. D. Jackson, Classical Electrodynamics, John Wiley & Son, New York, 1962.
2. D. Tomboulian and P. Hartman, Phys. Rev. 102, 1423 (1956).
3. J. Schwinger, Phys. Rev. 75, 1912 (1949).

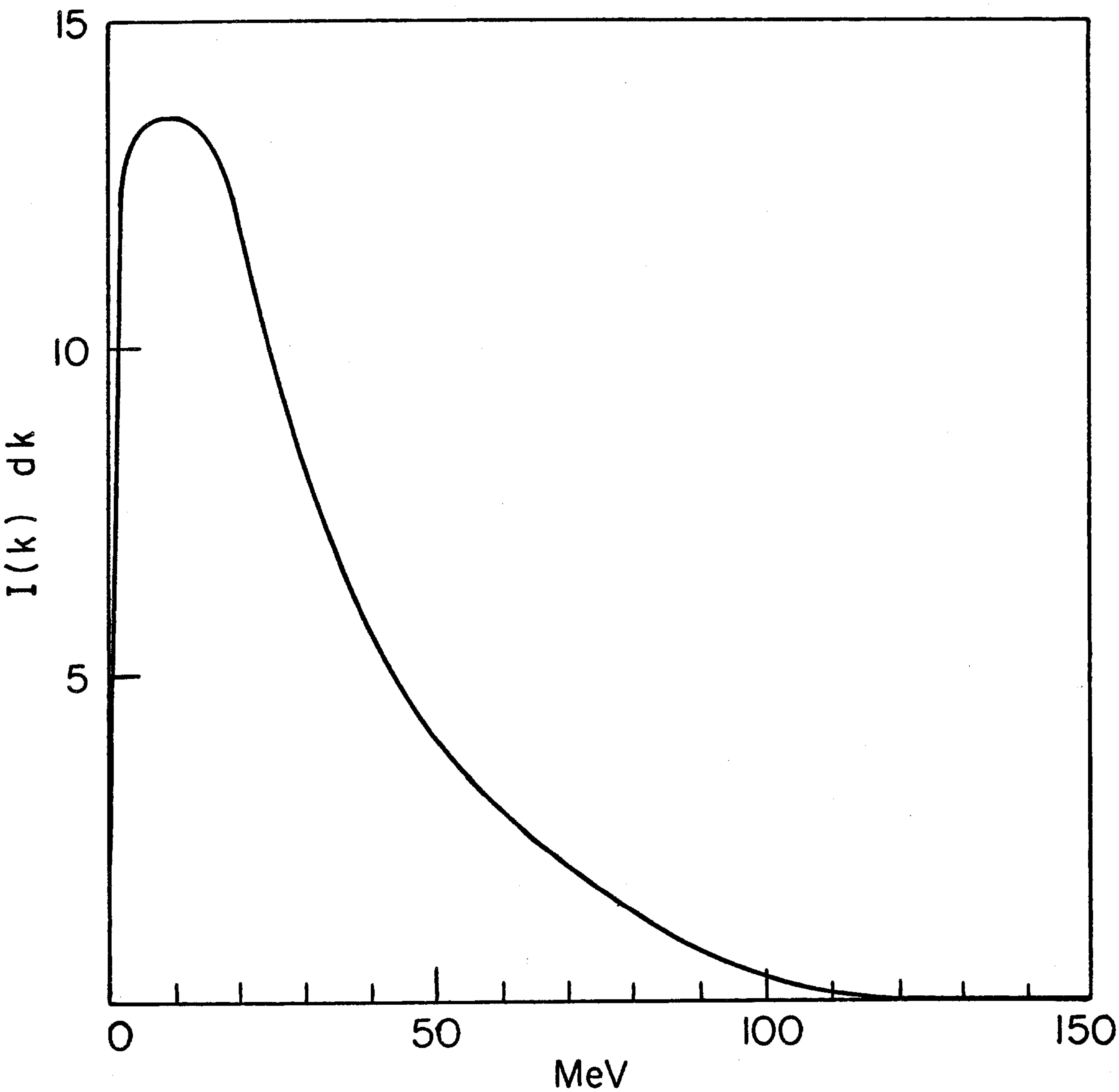
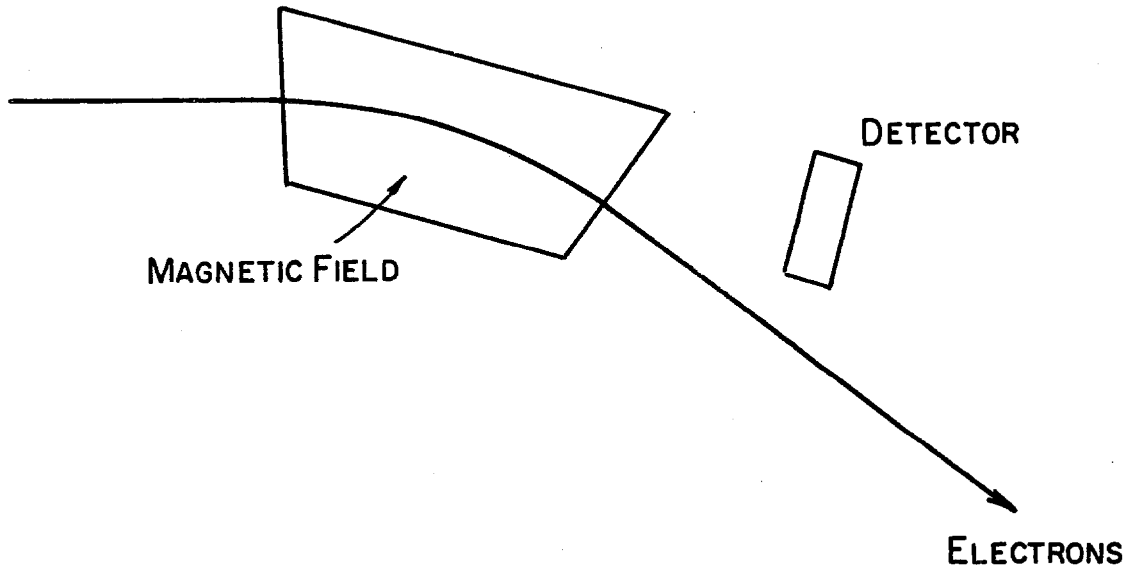
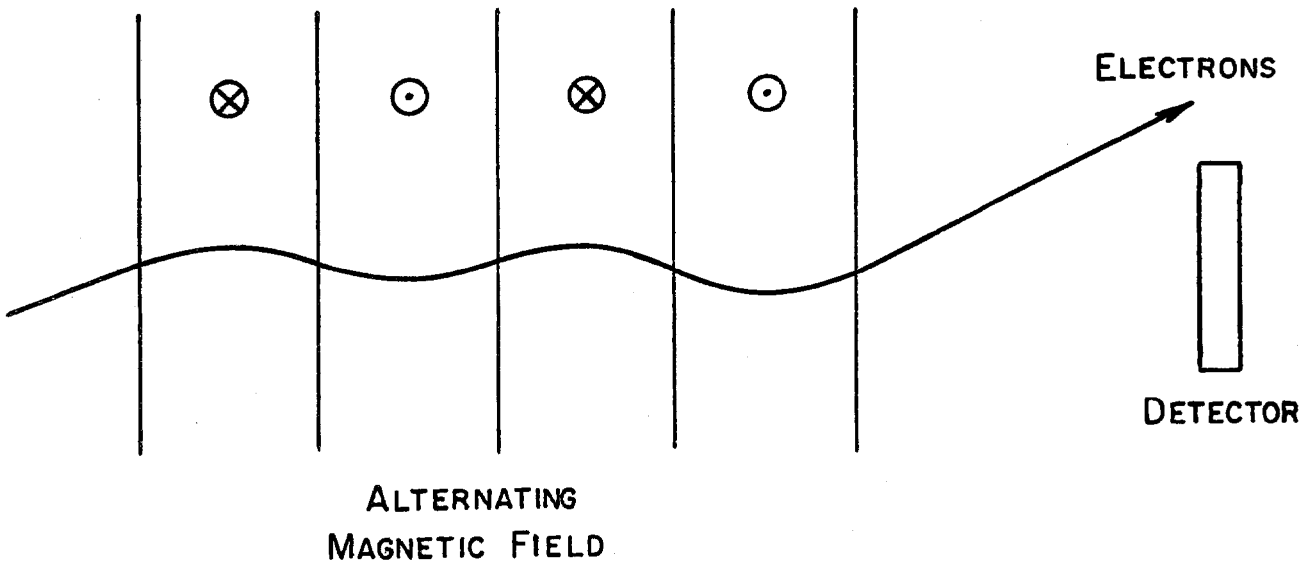


Fig. 1. Spectrum of synchrotron radiation from a 100-GeV electron.



(a)



(b)

Fig. 2(a). Synchrotron radiation detector. (b) A more sensitive arrangement using an alternating magnetic field.